EFFECTS OF KENAF/POLYESTER BLENDING RATIOS ON PHYSICAL AND MECHANICAL PROPERTIES OF YARNS PRODUCED FROM RING SPINNING SYSTEM

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DEDICATION

***For My beloved Parents**. My Father with his endless encouragement and motivations. My Mother for her endless love, care and prayers. Thanks for always being there for me.*

***For My beloved one**, for your helping supports and your ways of making me smile, also become my financial, **for my friend** in action, thanks for the best wishes.*

I thank all of you

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ABSTRACT

Yarns with natural-synthetic hybrid fibers are becoming increasingly popular with the increase of environmental awareness. This is mainly because the hybridization of fiber may reduce the use of synthetic fibers in the making of yarns. Note that polyester, an excellent synthetic fiber, is difficult to be recycled and is non-biodegradable. On the other hand, kenaf fiber has been proven to be biodegradable and compatible with the environment. This study observed on properties of kenaf/polyester hybrid yarns with different composition of kenaf that was spun using ring spinning system. The development of sliver was prepared by using carding process, the sliver was then inserted into ring spinning machine to produce hybrid yarns. The physical and mechanical analysis such as surface morphology, diameter of sliver and yarn, waste percentage, size and tensile strength test were conducted on sliver and yarn. Apart from that, the Analysis of Variance (ANOVA) via Minitab software was employed for quantitative evidence, and the morphology analysis of different kenaf composition was observed through Scanning Electron Microscope (SEM). At the beginning of this study, the optimum characteristics of kenaf/polyester sliver subjected to the different composition of kenaf were determined. Following this, kenaf/polyester hybrid yarn of three different weight ratios were developed (50:50, 60:40 and 70:30). The findings showed that the physical and mechanical properties of sliver and yarn could be effectively controlled by varying kenaf composition. The composition of 50% kenaf exhibited an excellent stress-strain response, tensile strength, Young's Modulus and elongation percentage. The adhesion effects of both kenaf and polyester fibers created an interlocking structure that limited the extension of the yarns. This produced fibers with a higher bending load capacity. It was also noted that the kenaf/polyester hybrid (50% kenaf and 50% polyester) had improved physical and mechanical properties. Nonetheless, the subsequent increment in kenaf composition did not improve the strength of the yarn.

ABSTRAK

Penghibridan antara gentian sintetik dan gentian semulajadi dalam pembentukan benang telah mendapat perhatian dalam bidang penyelidikan. Ini adalah disebabkan oleh peningkatan dalam kesedaran terhadap kepentingan menjaga dan melindungi alam sekitar. Penghibridan antara gentian kenaf dan polyester dijangka dapat mengurangkan penggunaan gentian sintetik. Poliester telah dikenal pasti sebagai sejenis gentian sintetik yang sukar untuk dikitar semula. Sebaliknya, gentian kenaf telah dibuktikan sebagai gentian yang mudah untuk dikitar semula. Penyelidikan ini telah menfokuskan kajiannya untuk menentukan sekiranya terdapat sebarang penambahbaikan ke atas yarn yang diperbuat daripada gabungan poliester dan komposisi kenaf yang berbeza dengan menggunakan kaedah ‘ring spinning’. Permulaanya, penghasilan sliver melalui kaedah ‘carding’ proses dan kemudiannya sliver tersebut dihasilkan menjadi yarn melalui kaedah ‘ring spinning’ proses. Dalam kajian ini, analisa fizikal dan mekanikal telah dijalankan terhadap sliver dan yarn termasuklah analisis morfologi, ukur lilit sliver dan yarn, peratusan sisa, saiz, dan kekuatan tegangan. Analisis Varians (ANOVA) telah digunakan untuk mendapatkan keputusan statistik untuk menyokong hasil kajian. Selain itu, analisa morfologi untuk komposisi kenaf yang berbeza telah dikaji menggunakan Pengimbasan Mikroskop Elektron (SEM). Pada peringkat permulaan kajian ini, ciri-ciri optimum untuk yarn kenaf-poliester yang berbeza komposisi kenaf telah ditentukan. Tiga jenis yarn dengan nisbah kenaf-poliester yang berbeza telah dibangunkan (50:50, 60:40 dan 70:30). Jenis yarn dengan 50% komposisi kenaf mempunyai tegasan, kekuatan tegangan, Young’s modulus, dan peratusan pemanjangan yang baik. Kesan lekatan kenaf dan serat poliester dalam yarn telah mewujudkan struktur saling berkait yang membataskan pemanjangan benang serat sepanjang arah. Penghibridan kenaf-poliester (50% kenaf dan 50% polyester) juga telah menunjukkan hasil yang sangat baik dalam sifat fizikal dan mekanikal yarn. Selain itu, peningkatan kadar komposisi kenaf dalam penghasilan yarn tidak menambahkan kekuatan yarn tersebut.

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LIST OF SYMBOLS AND ABBREVIATIONS

AHP	Analytical Hierarchy Process
ANOVA	Analysis of Variance
ASTM	American Standard Testing Material
Av.	Average
BRIS	Beach Ridges Interspersed with Swales
CO_2	Carbon Dioxide
DF	Degree of Freedom
IUCN	Union for Conservation of Nature
LKTN	National Kenaf and Tobacco Board
MARDI	Malaysian Agricultural Research and Development Institute
MESTECC	Ministry of Energy, Science, Technology, Environment and Climate Change
MRB	Malaysia Rubber Board
MS	Mean Square
NF	Natural Fiber
R&D	Research and Development
RMK11	Rancangan Malaysia ke-11
SEM	Scanning Electron Microscope
SS	Sum of Square
UTM	Universal Testing Machine

CHAPTER 1

INTRODUCTION

1.1 Background

Kenaf is a cellulosic fiber that is in the same category as cotton. It is an annual crop originating from Africa with increasing commercial important in many countries. Following this, kenaf plants are now grown abundantly in countries, such as India, Bangladesh, Malaysia, Indonesia, the United States, Thailand, and Vietnam [1]. Kenaf has a long history of cultivation similar to jute, but it is more lustrous and has better tensile strength [2]. It is made of two types of fibers, namely the outer bark (bast) and the inner woody core. The bast fiber constitutes 35% of the core with short fibers, which makes 65% of the plant [3]. The kenaf plant is unbranched and grows quickly to a height of 8 to 20 ft over a period of 4 to 5 months [4].

Kenaf is a multipurpose plant. Its leaves, tender shoot, woody core, bast fibers, and seeds are all valuable. The end products of kenaf fibers depend on the portion of the fiber used [1]. It is worth noting that kenaf fibers are usually highly in demand for their stalk from which fibers are extracted. Traditionally, the allied fibers are used as cords, ropes, and twines [5], and many studies have shown that they can potentially be used as reinforcement materials for composites. Kenaf fibers are also lightweight and environmentally friendly. Yuhazri et al., who examined the mechanical properties of kenaf-polyester reported that kenaf-polyester processed through vacuum infusion can replace the existing materials with better strength, lower cost, and increased environmental friendliness [6].

The interest in using natural fibers (NFs) to replace synthetic materials in the textile industries has increased simultaneously with the need for sustainable development and the growing environmental consciousness [7]. NFs offer advantages, such as low cost, unlimited availability, sustainability, and lightweight. Most importantly, NFs are biodegradable, recyclable, carbon dioxide neutral, and their energy can be recovered in an environmentally acceptable manner [8-9]. Apart from that, NFs can be structured to achieve a specific strength, but they have poor strength properties due to low density [10-11]. During a landfill or combustion process at the end of their life cycle, the released amount of carbon dioxide from the fibers is neutral with respect to the embraced amount during their growth. Compared to synthetic fibers, the abrasive nature of NFs is much less [9].

In Malaysia, the international and local demands for kenaf have increased rapidly [12]. Research and development (R&D) on kenaf in Malaysia began in 2000 and was pioneered by the Malaysian Agricultural Research and Development Institute (MARDI), the Malaysian Rubber Board (MRB), the Malaysian Palm Oil Board (MPOB), and Universiti Putra Malaysia (UPM). Kenaf cultivation was first introduced in 2004 as a plant introduction (familiarization crop). Meanwhile, the verification of crops was implemented in Kelantan and Terengganu on Beach Ridges Interspersed with Swales (BRIS) soil that was previously planted with tobacco [12]. Then, kenaf plantation spread to the rest of Malaysia in 2010. The National Kenaf and Tobacco Board (NKTB) plays a major role in supporting the development of kenaf and the tobacco industry. Based on the statistics of kenaf planting from 2012 to 2016 by NKTB, the successful cultivation of fiber has increased by 99.6% from 2015, achieving the target of 2500 hectares set for 2016 (Table 1.1) [13].

The long dry season in tropical areas causes the kenaf seeds to be produced mostly in the Northern Region of Malaysia. Kenaf plants are considered to be the alternative and versatile fiber crops as they are completely biodegradable, renewable, environmentally friendly, and do not require a significant amount of chemical in their processing or cultivation [13-14]. Nonetheless, only a few researchers investigated the process of converting kenaf fibers into yarns. Most of the research focused on the composites. Jeyanthi and Rani reported that kenaf-glass hybrid reinforced composites can be utilized for passenger car bumper beams [15]. Juliana and Paridah also claimed that kenaf stem is valuable for particle-board manufacturing. This claim is based on the high-density property of the stem. Apart from that, kenaf fibers can also provide pulp to the newsprint industry [16].

Table 1.1: Kenaf planting statistic from 2012 to 2016 by LKTN [13]

State	Year of Fiber and Core Production Plant Area (Hecta)				
	2012	**2013**	**2014**	**2015**	**2016**
Kelantan	301	510	634	715	842.58
Terengganu	314	260	510	433	666.30
Pahang	642	865	706	829	693.90
Kedah	-	-	-	25	55
Perlis	-	-	-	50	110
Selangor	-	-	5	3	-
Perak	30	105.00	125.00	131.00	50.00
Negeri Sembilan	23	18.00	-	-	-
Johor	21	66.00	-	50.00	70.00
Pulau Pinang	-	-	20.00	25.00	15.00
Melaka	-	-	-	13.00	-
Total	**1,331.00**	**1,824.00**	**2,000.00**	**2,274.00**	**2,502.78**

There is a rapid and substantial development of technology in the textile industries to meet customer demand. However, major environmental challenges to the textile industries also follow this development [17]. The textile industries are under pressure to reduce pollutant emissions [18]. This drives the textile manufacturers to seek new approaches to produce environmentally friendly products, such as recyclable and biodegradable textile materials. This is supported by the continuing and increasing dominance of polyester, as computed by the Textile Exchange from 1960 until 2016 (shown in Figure 1.1). Polyester demand will surpass cotton in 2002 and has continued to grow at a significantly faster rate than other fiber types. Following this trend, the textile industries are obliged to reduce pollutant emissions caused by synthetic fiber. The work significantly contributes to the Eleventh Malaysia Plan (11MP); Malaysia's green growth strategy to reduce activities that negatively impact the environment, and manage the natural resources wisely.

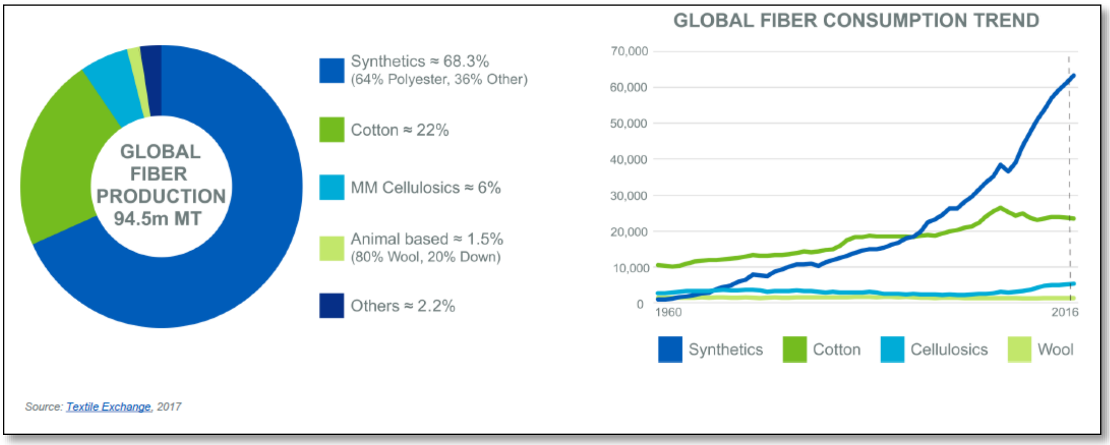

Figure 1.1: The continuing dominance of synthetic fiber [17]

One of the downstream processed is to spin the new NFs, for instance, spinning kenaf fibers into yarns. However, this has typically been a challenge since kenaf fibers are somewhat brittle and coarse, making them extremely difficult to spin by using any of the modern spinning systems [51]. One alternative is to blend the fibers with other conventional fibers, such as polyester and spin them using the ring spinning method.

In this research, a kenaf yarn was produced through a spinning process that is commonly used for short staple fibers. The spinning process is the process of obtaining yarns by using the rotation movement and difference in spin velocity of several shafts. The spun yarn spinning process consists of four stages, which are carding, drawing, roving, and spinning. Prior to yarn development, the kenaf fibers underwent water retting [53].

Furthermore, the spinning method was performed by varying the spinning speed. This was done to investigate the most effective spinning speed for yarn development. This research successfully developed a yarn with better mechanical properties than other NFs, such as high in tensile strength, elongation, breaking load, and Young's modulus [54]. With regard to the textile industries, this research managed to invent a high-quality yarn and may also potentially improve the economy of the kenaf industry due to the increasing demand for kenaf fiber.

1.2 Problem statement

Currently, one of the major challenges in the textile industry is related to environmental problem, specifically the great pressure to reduce pollutant emissions. This is especially important in terms of synthetic fiber usage, such as polyester, whereby the use of synthetic materials has become a great concern in influencing human life. To reduce such dependency on synthetics, the hybridization on natural and synthetic fibers in yarn production has gained scholarly attention due to rising environmental concern. Fiber hybridization is expected to reduce synthetic fiber consumption in yarn manufacturing [7]. The research attempted to explore the potential hybridization between kenaf and polyester. The motivation to conduct using polyester as the materials for hybridization because due to the polyester known as a synthetic petroleum-based fiber, which is made from carbon incentive non-renewable resources. More than 70 million barrels of oil are used to make polyester annually, but it is non-biodegradable and will persist in the ecosystem even as it eventually breaks apart [9].

Such situation has driven textile manufacturers to seek new approaches for the production of environmentally-friendly products, such as recyclable and biodegradable textile materials. Exploration of natural fibers as proven its benefits of being renewable and biodegradable [19]. Therefore, more attention is directed towards agricultural products, waste, and derivatives due to their renewability. An example on cops being investigated is kenaf, which is an old crop with many uses. Kenaf fiber has been highlighted as a strengthening agent, whereby the strong fiber is highly potential for use in technical applications [20]. The idea of making yarns from kenaf has been established since the early 1990s; however, the yarn quality is inadequately suitable for making fabrics and apparel [21]. Therefore, this project will help in developing and refining the methods of improving processing for textile applications. The project also focuses on hybridization of kenaf/polyester with three different blending ratios are 50:50, 60:40, and 70:30 by weight percentage. The ratios were chosen as referred on previous research which was successfully conducted using 5:95, 10:90, and 15:85 kenaf/polyester by weight percentage using rotor spinning [79]. So, by referring to previous research study, this project tries to increase the kenaf usage in yarns formation by using different spinning methods.

Kenaf is a very rough and coarse fiber. Running it through the ring spinning process is not possible, which causes polyester to be blended with it. Not only it will help in the spinning process, such method can also reduce polyester fiber usage, which is one of the most utilised synthetic fiber in the textile industry. Therefore, this study uses natural kenaf fiber blended with polyester to produce hybrid yarns for analysing their physical and mechanical performance. Besides, the kenaf/polyester hybrid yarn is further subjected to an analysis in assessing the effect of diameter, evenness and percentage of elongation on the tensile strength performance.

1.3 Research objectives

The research objectives are:

i) To investigate the physical properties of kenaf/polyester sliver produced from the carding process in terms of appearance, diameter, size and kenaf waste percentage.
ii) To analyse the physical and mechanical properties of kenaf/polyester yarn subjected to different blending ratios.
iii) To recommend the best blending ratio of the kenaf/polyester yarns based on the physical and mechanical properties.

1.4 Research scope

The scope of this study includes:

i) Kenaf fibers were supplied by Kenaf Bi Solution Sdn. Bhd. Kuala Lumpur, Malaysia.
ii) The kenaf and polyester fibers underwent the opening proses using the opener machine at FIDEC, Banting. The kenaf and polyester fiber were weighed using three different weight ratios which were (50:50, 60:40 and 70:30).
iii) The sliver was produced using a carding machine and the parameters of the main cylinder, outlet speed, inlet speed and twister were kept constant at 43 rpm, 25 rpm, 16.8 rpm and 17.9 rpm, respectively.
iv) Ring spinning machine was used to produce the kenaf/polyester yarn.

v) Evaluation of sliver physical analysis included diameter (ASTM D2130-90), waste percentage, microscopic view and sliver size.

vi) The physical properties that were analyzed for the yarn were diameter, and evenness.

vii) For mechanical properties, the tensile strength test was conducted to determine responses, such as elongation, Young's modulus, maximum breaking load, and stress strain according to ASTM D2256.

viii) The kenaf/polyester yarn structure was observed using Scanning Electron Microscope (SEM).

ix) Analysis of variance (ANOVA) was employed to determine the significant factors that predominantly influence the yarn properties.

1.5 Significance of study

The thesis has various significant towards furthering the understanding on the response of kenaf/polyester blended yarn. The contribution is briefly summarized as follows, which specific results are detailed in Chapter 4 and the final conclusion expressed in Chapter 5. The significant of the study will produce positive outcomes toward the government, industry and community.

i) Government

The research support and contributes to the Eleventh Malaysia Plan (RMK11) particularly to implement the green growth. Among the trajectory outcome of the green growth strategy are to reduce the activities which lead to the negative impact to the environment and to manage our natural resources wisely and sustainably. This work also aligns with the MESTECC Incentive 2019 which is focusing on environment and climate change

ii) Industry

The level of depending for cotton and polyester in textile manufacturing increase gradually. In Malaysia, there is no cultivation of cotton, while polyester is a synthetic fiber. So, by applying the kenaf in our textile industry, we can reduce the cost of buying an import fiber and also reducing pollutant by using environmentally friendly fiber

iii) Community

Textile industry is closely related to the community, by conducting an aggressive research toward textile industry the community, also can received a positive impact. New discover can improve the society way of appearance. Moreover, the community is the major consumer for the textile industry, thus by develop the yarns using kenaf, it can support the diversification of income generation to community

1.6 Thesis outline

The inscription of the thesis has been divided into five chapters. Chapter 1 gives the whole general information about the idea of the research, including the problems and issues related. This chapter also highlights the aims and objectives of the research, besides emphasizing on the research contributions. Chapter 2 provides a review of the literature related to the aims and objectives of the thesis. Areas where further research is required were identified, thereby positioning the aims of the thesis. Topic reviewed include the general introduction about the kenaf, method to process in development of yarn on ring spinning process, analysis and testing on the yarn. Chapter 3 embraces a whole experimental procedure, including the information on raw materials, sample preparation, characterization, and testing and analysis method. Chapter 4 involves the interpretation of the results and findings for all research objectives in order to gain a better understanding. Finally, Chapter 5 summarizes and concludes the results of the present study and propose some recommendation for future works.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, an in-depth review of literature comprising previous research was discussed which will be utilized as supportive evidence for the current study. This chapter also explains the spinning technology that is used for the manufacture of kenaf-based products, as well as summarizing related research about the characteristics of kenaf which are vital before any experimental setup.

2.2 General properties of natural fiber

Natural fiber (NF) can be classified and defined as substances that are derived from either plants or animals that can be spun into filament, thread or even rope [26]. A several characteristics that make natural fiber a useful raw material because they are inexpensive, ample, highly available and could be obtained in a billion-ton all around the world [26-27]. Fibers are class of hair-like material that forms continuous filaments or are in discrete elongated pieces, ends as thread [27]. They can be used as a component of composites materials. They can also be matted into sheets to make products such as paper or felt [28]. Figure 2.1 illustrates the various types of natural fiber.

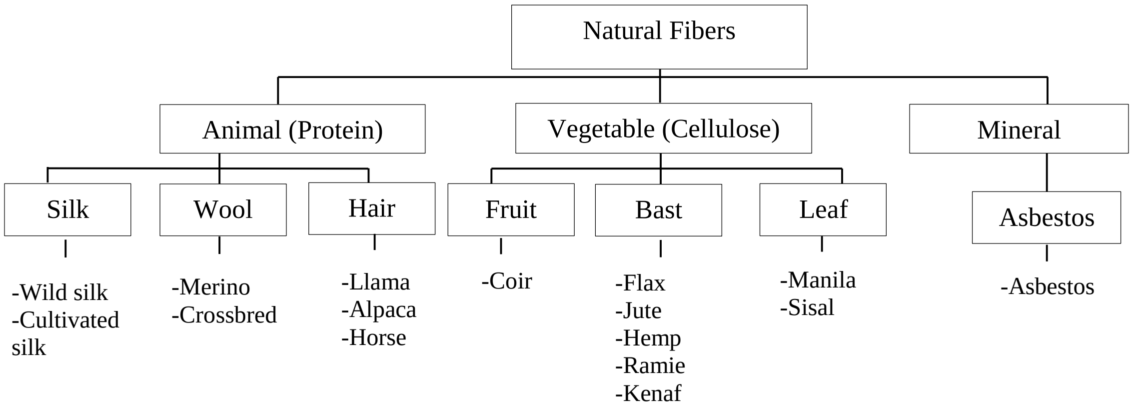

Figure 2.1: Type of natural fiber [26]

Natural fiber is a sustainable raw material for the manufacturing industries because of the characteristics mentioned earlier. There are many advantages of using natural fibers primarily because of its specific modulus, cost per weight, and cost per unit length along with its renewable and biodegradable nature [27]. The development of natural fiber reinforced biodegradable polymer composites promotes the use of environmentally friendly materials in manufacturing. The use of green materials provides an alternative method to solve the problems associated with agriculture residue. Apart from that, other positive features of natural fiber include its high level of toughness, low in density, it reduces tool wear, has comparable specific strength properties, requires low fabrication energy, has ease of separation as well as high in carbon dioxide (CO_2) neutrality or sequestration [28]. Natural fibers are rigid with low-density crystalline cellulose when compared to synthetic fibers. Sakthivel et al., reported that natural fibers have many advantages compared to glass fibers because of their low density, and they are recyclable and biodegradable [29]. Additionally, they are renewable raw materials and have relatively high strength and stiffness. However, bast fibers such as flax, jute, and kenaf have a higher tensile strength compared to other fibers. Table 2.1 compares the physical and mechanical properties of natural fiber and synthetic fibers.

Table 2.1: Physical and mechanical properties of natural fibers and synthetic fibers [29]

Fibers	Density (g/cm^3)	Diameter (mm)	Tensile strength (MPa)	Elongation at break (%)
Flax	1.50	0.04-0.60	345-1500	2.70-3.20
Hemp	1.47	0.03-0.50	690	1.60
Jute	1.30-1.49	0.03-0.20	393-800	1.16-1.50
Kenaf	1.20	0.04-0.16	180-930	1.60
Ramie	1.55	-	400-938	1.20-3.80
Cotton	1.50-1.60	0.01-0.04	287-800	7.0-8.0
Coir	1.15-1.46	0.10-0.46	131-220	15-40
E-glass	2.55	0.01	3400	2.50
Kevlar	1.44	-	3000	2.50-3.70
Carbon	1.78	0.005-0.007	3400-4800	1.40-1.80

2.3 Kenaf fiber

Kenaf (*Hibiscus Cannabinus L., Malvaceae*) is known as the annual fiber crop, tall and slender, resembling bamboo and jute, kenaf is in the hibiscus family, and is related to cotton (*Gossypium hirsutum L., Malvaceae*) and okra (*Abelmoschus esculentus L., Malvaceae*). This is a 4000 years old crop, originating from Africa. Kenaf is also known for its multiple layers and good outer fiber and is generally separated into two components: the bast, and its core. These two components have distinct usage. The fibrous outer layer or bast is used as a cordage crop to produce twine, rope, carpet backing, burlap, and sackcloth for over six millennia. The core, on the other hand, is very absorbent, and one of its many uses is to clean up oil spills on water. The core is also used for insulating panels and animal bedding [30].

There have been many studies conducted about the usage of kenaf, and current research is focused on the utilization of kenaf as building materials, as oils absorbents, in the textiles and automotive sectors. Kenaf is also utilized to improve the production of paper-based products because it produces higher quality paper products [31]. As indicated by the European Guideline 2000/53/EG regulated by the European Commission, 85% of the weight of a vehicle must be recyclable by 2005. This recyclable rate will be expanded to 95% by 2015. Vehicles must be built from 95% recyclable materials, with 85% of the materials recoverable through reuse or mechanical reusing and 10% through vitality recuperation or warm reusing. The regulation will lead to an increase in the use of natural fibers such as kenaf, jute, flax, and hemp. The natural fibers reinforced composites have attracted considerable attention in the automotive industry and today research has developed these reinforced composites because natural fibers offer certain benefits, such as being lightweight, low cost, and renewable. The recognition of kenaf as a potentially commercial crop as well as being exploited for the industry had been verified by the National Kenaf Research and Development program in Malaysia. Considering the versatility of kenaf in term of being biodegradable, renewable and environmentally friendly, kenaf is a suitable alternative to raw materials [31].

Raw kenaf fiber that is obtained from the outer bark of the kenaf plant is made from a bundle of lignocellulose fibers. The size of the fiber bundle depends on the number of ultimate cells in each bundle. Kenaf contains approximately 65.7% cellulose, 21.6% lignin and pectin, and other composition. Most of the lignin is present between the ultimate cells. To enable the separation of the fiber, the lignin must be extracted first [32].

Another researcher stated that a single kenaf fiber also can be found about 1-7 mm long and about 10-30 microns wide [33]. The different in diameter of a single kenaf fiber might be due to different process, country that planting the kenaf, and by other external factor such as light, water and nutrients [77]. The vast amount of sample study does not require a specific average length of the sample. Figure 2.2 shows the photomicrographs of an individual kenaf fiber and a fiber bundle [33].

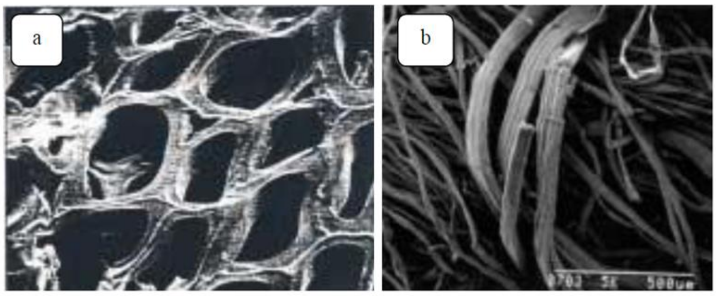

Figure 2.2: Kenaf fiber; (a) Individual fiber cross section 3000x, and

(b) Fiber bundle [33]

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